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J. STALEY ET AL
METHOD AND APPARATUS FOR PRODUCING INSULATED
ELECTRICAL CONDUCTOR

3,270,401

Original Filed Jan. 7, 1957

2 Sheets-Sheet 1

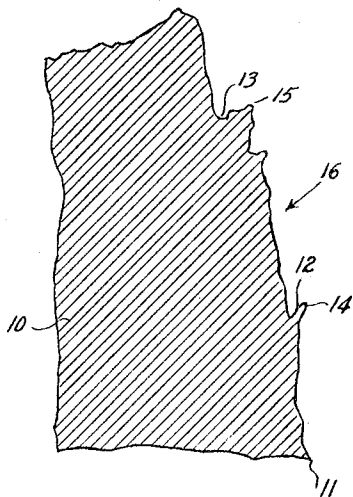


Fig 1

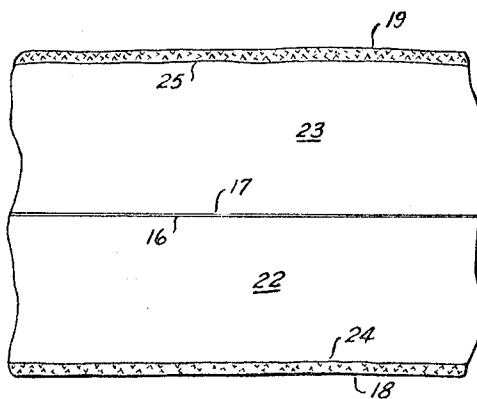


Fig 3

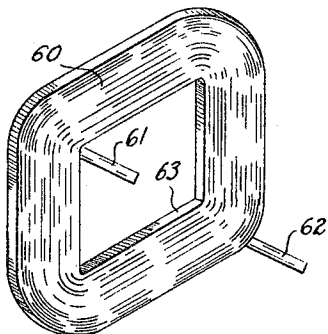


Fig 4

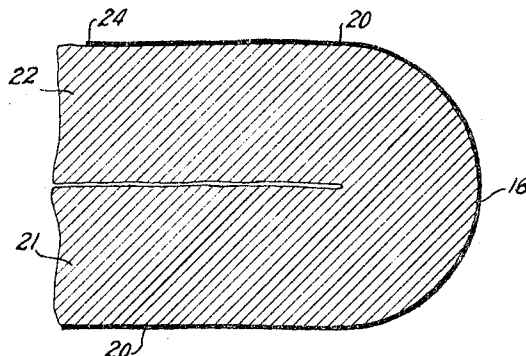


Fig 2

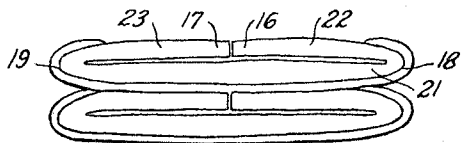


Fig 5

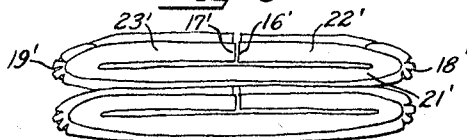


Fig 6

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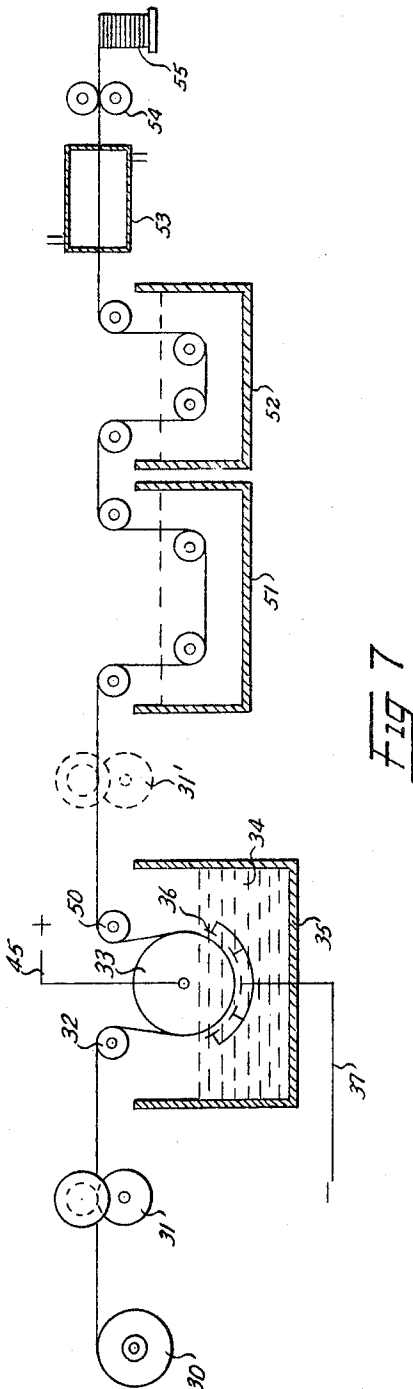
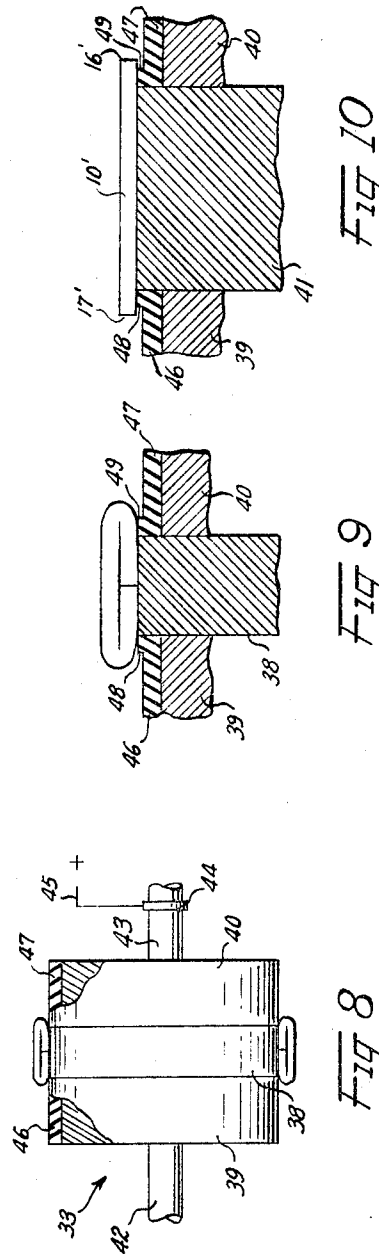
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METHOD AND APPARATUS FOR PRODUCING INSULATED ELECTRICAL CONDUCTOR

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Original application Jan. 7, 1957, Ser. No. 632,809. Divided and this application Aug. 28, 1962, Ser. No. 226,194

8 Claims. (Cl. 29—155.57)

This invention relates to a new and improved thin strip conductor suitable for fabrication into electrical coils, as well as to an improved method and apparatus for producing that conductor as an intermediate article of commerce. This application is a division of the applicants' copending application Serial No. 632,809 filed January 7, 1957, and now abandoned. In the application Serial No. 487,057 filed February 9, 1955, which was copending with said parent application and is now abandoned, we, together with Clarence A. Manning, have disclosed certain aluminum strip electromagnetic windings and method in which an intermediate article is provided with rounded lateral edges by means of a brushing operation. We now have found that, by following the practices hereinafter set forth, an improved strip conductor of that general type may be produced by a folding operation.

As set forth in the aforementioned earlier application, much difficulty has been encountered in the past when applying an insulating coating to the irregular or burred edges of a thin strip of conductor material, such as aluminum foil. Such irregular edges are produced when the conductor is cut from sheets of commercial width. When viewed under the microscope the strip discloses sharp points, corners, and various other forms of non-symmetry at its edges, all of which militate against the formation of a uniform coating providing a standardized insulating value.

In the above mentioned copending application, a useful process and means is shown for making the new product described and claimed therein which overcomes the prior disadvantages and wherein the conductor strip has its irregular edges rounded, as a specific example, by means of a separate brushing operation prior to application of the insulating coating thereto. While that invention provides a great advance in the art, it nevertheless is expensive and inconvenient for treating thin or narrow strips as compared with the present invention.

One object of this invention is to provide a new and improved strip conductor as an intermediate article of manufacture.

Another object is to provide a new and improved electrical coil having characteristic insulating properties attributable to the strip conductor from which it is formed.

Another object is to provide an improved method and apparatus for forming insulated strip conductors.

Another object is to provide a relatively inexpensive strip conductor insulated in selected regions thereof.

Another object is to provide an improved method and apparatus for depositing an anodic coating upon a continuously moving strip of aluminum.

Other objects and advantages will become more apparent when considered in conjunction with the accompanying drawings showing a presently preferred form of folded conductor and apparatus for producing the same.

In the drawings,

FIG. 1 represents a microphotograph of the right hand edge portion of a cross section at a cut edge of a conventional aluminum foil strip of 0.008" thickness, showing the burred irregular edge even after a very careful slitting of the strip.

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FIG. 2 represents a right hand edge portion of a cross section of the same strip when folded and provided with an anodic insulating coating in accordance with this invention, but shown to a much smaller scale.

FIG. 3 is a plan view to a much smaller scale of the treated strip conductor of FIG. 2 and showing the folded edges.

FIG. 4 is a perspective view of a typical electrical coil formed from the treated strip conductor.

FIG. 5 is a diagrammatic view of two adjacent turns of the coil of FIG. 4 when formed of our improved strip conductor which has an anodizing step subsequent to the folding step, the coating being greatly exaggerated.

FIG. 6 is a diagrammatic view of two adjacent turns of the coil of FIG. 4 when formed of our improved strip conductor which has an anodizing step prior to the folding step, the coating being greatly exaggerated.

FIG. 7 is a diagrammatic view illustrating apparatus suitable for carrying out a preferred procedure pursuant to the invention.

FIG. 8 is an elevation view of one form of anodizing roller suitable for carrying out the invention with either a pre-folded or a non-folded strip conductor.

FIG. 9 is a detail view of the roller as used with a pre-folded strip; and

FIG. 10 is a detail view of the roller as used with a non-folded strip.

In accordance with our invention, we form a strip conductor of desired final dimensions from a flat sheet of suitable stock material initially having an oversize width and an undersize thickness. The stock material, for example, may be an aluminum foil of suitable gauge and width acceptable for the end purposes of the conductor. During the formation of the conductor, the sheet of stock material is folded; is provided with an insulating coating; and may receive other additional treatments. The sequence of folding and coating of the stock material may be varied, depending upon the end use of the conductor. One feature of the invention is the flexibility of choice provided the user in that many sizes of stock material may be employed; many varieties of coating materials may be used; many different ratings in insulation properties of electrical elements formed from the treated conductor may be secured; all without departing from the scope of the invention. When using aluminum foil or sheet as the stock material, the initial thickness of the sheet may be in the range of 0.00017 to 0.060 inch, the lower portion of this range being much thinner than that of stock sheets which can be conveniently treated by the brushing procedure set forth in the aforementioned application. Normally, the insulating coating will have a thickness of about 0.0001 to 0.001 inch, when an anodic coating is used, but if other types of coatings are used much thicker insulation may be employed. Thus, by means of our invention, extremely thin insulated conductors may be fabricated into coils, windings and the like (all hereinafter designated as coils) for use in electrical apparatus wherein space is an important factor, as in the minaturization of known types of equipment.

Referring now to FIG. 1, a typical edge 16 of a conventional sheet 10 of coil cut by a slitting operation, and when suitably magnified, will be seen to have an uneven shape including such irregularities as sharp corner 11, sharply convergent recesses 12 and 13, sharp projections 14 and 15 and the like. It will be understood that the second irregular edge 17 of the same sheet is of substantially the same configuration as edge 16 and is parallel thereto. When such a sheet has an insulation coating applied thereto, only an inadequate amount is deposited on the surface at the most marked of the irregularities. We have now discovered that this inherent dis-

advantage of the slit sheet stock may be overcome and that other unexpected advantages may be secured by forming the sheet 10 into a folded configuration, as noted in FIGS. 2 and 3. Preferably, the folding occurs prior to the deposition of the insulating coating, although, in certain usages, the deposition may occur first. If the coating is applied before folding, it may be in the form of a thin sheet of insulating material.

As is known, the use of an anodized film on aluminum provides an excellent insulation therefor. Such an inorganic coating is not only a more permanent type of insulation, but also it allows operation of electrical equipment at higher temperatures than do the conventional organic insulations. Thus, for a given insulating value, an anodized film can have a smaller thickness, thus contributing to a more compact form of coil. Furthermore, the deposition of an anodized film can be controlled as to depth and as to areas to be coated, thus to avoid the deposition of excess insulation at points where such is not required. However, the coating of a conductor with an anodizing film by means of conventional processes is a relatively expensive, slow and exacting operation. In particular, the heating effects caused by current flow through the conductor from a relatively distant point to the vicinity of the anodes has limited the rapidity with which the film may be deposited. By means of the process and apparatus now to be described, we are enabled to a substantial degree to avoid the disadvantages of these prior practices.

Referring now to FIG. 7, a roll 30 of conductor sheet material having first and second flat surfaces joined by parallel irregular edges 16 and 17 and with a width approximately twice, and a thickness of approximately half, the respective dimensions of the final conductor, is provided. It will be understood that this roll 30 preferably comprises a sheet which has been recently cleaned in a hot mild alkaline solution and then rinsed thoroughly in cold water, accordingly to conventional practice for preparing aluminum for anodic treatment. From roll 30 the web is led continuously through suitable folding rolls 31 which are represented schematically in the preferred form of our invention. These rolls include an ironing roll (not shown) which flattens the strip after the folding. The folding is accomplished by known techniques and may use one or more dies for the folding. As the web passes from these rolls the bare conductor strip is in the longitudinally folded form, as seen in FIG. 3, with the irregular edges 16 and 17 being disposed in closely abutting relation and, most significantly, with the intermediate longitudinal portion of the strip bent in smoothly curved parallel edges 19 and 18. As noted in FIG. 2 the curved edge 18 (as well as curved edge 19) is devoid of the irregularities found in edges 16 and 17 and thus is adapted for receiving a substantially uniform anodic insulating coating 20. As will later appear, in the preferred form of the invention, the lower non-folded portion 21 of the conductor receives the coating over its entire surface whereas the upper folded portions 22 and 23 receive the coating only to a limited extent. In general, we prefer to deposit the coating on those folded portions around edges 18 and 19 terminating the coating along parallel lines 24 and 25, which lines lie at a distance from the rounded edges equal to about 2-3 times the thickness of sheet stock 10.

Reverting now to FIG. 7, the folded bare strip continuously moving from rolls 31 passes over guide roll 32 and is directed into tight engagement with the surface of an improved electrolytic roller 33, rotating in an electrolytic bath 34 contained in tank 35. For purposes of illustration, this tank may contain an anodizing solution consisting of an aqueous solution of sulfuric acid at a concentration of about 15-18% and held at a temperature of about 70 degrees F.

Spaced closely adjacent the outer surface of the bare strip moving through the tank, is a plurality of suitably

shaped cathodes 36 submerged in the electrolytic bath and connected to the negative conductor 37. As a significant feature, current flow through the conductor undergoing electrolytic treatment is limited to the region thereof where such treatment is occurring. Thus, we avoid the heating caused by resistance losses in the conductor resulting from leading current from a remote positive terminal through that conductor into the region of the submerged cathodes. Accordingly, higher current densities may be used and the speed of travel of the conductor strip through the bath may be increased. Moreover, since we do not deposit an anodic film over the entire surface of the strip, the time required for the treatment is further reduced over that when the entire strip surface is to be treated. It will further be understood that these features contribute materially to a reduction in cost of the final product.

As noted in FIG. 8, we prefer to employ an electrolytic roller 33 having a central section 38 bounded by side sections 39 and 40, all sections of the roller being conductors and preferably being detachable from each other so that a substitute central section 41 of different size may be readily assembled into the structure when so desired. Transverse shaft members 42 and 43 serve to rotatably support the roller in tank 35 and are suitably insulated from that tank by appropriate insulating bearings, not shown. A slip ring connection 44 joins one of these shaft members to a positive conductor 45. It will be understood that the roller sections 38, 39 and 40 may be of any suitable structural material which will efficiently conduct electricity and which preferably is resistant to the chemical nature of the electrolytic bath. Preferably, these roller sections are of a suitable structural shape to reduce resistance losses in the circuit and to avoid the necessity of special means for the roller.

As a significant feature, the roller sections 39 and 40 are covered on their peripheral surface with a suitable resilient dielectric material such as rubber as indicated at 46 and 47. As best seen in FIGS. 9 and 10, these coverings, which provide a mask for portions of the conductor under treatment, may have shoulders 48 and 49 serving to determine the location of the edges 24 and 25 (FIG. 3) of the insulating coating being deposited. Moreover, these shoulders which are under compression as the roller is rotating with the strip in engagement therewith, prevent the flowing of the liquid electrolyte into the crevices in the interior of the pre-folded conductor shown in FIGS. 8 and 9.

Following a suitable period of anodic treatment, which, for example, may be about one-sixth to 25 minutes, preferably three minutes, from the time the moving web of strip enters the bath until it leaves the bath, and with a current density of about 10 to 100, preferably 50, amperes per square foot of conductor exposed to the bath, the web is directed over guide roller 50. Thence it is directed through tank 51 by means of suitable guide rollers, receiving in that tank a rinsing with water. Upon leaving the rinsing tank, the web is directed through separate tank 52 by means of suitable guide rollers, receiving in that tank a sealing of the anodized coating, by known methods, such as by means of hot water at a temperature of about 200 degrees F. Subsequent sealing by means of steam in pressure sealed container 53 may be applied to the moving web and, if desired, a further coating may thereafter be applied to the web, as for example, a silicone, a lacquer, or other type of conventional coating, if such is desired. It will be understood that such additional coatings form no essential part of the present invention, but are mentioned to illustrate the adaptability of our improved form of conductor for such treatment. Following the above-mentioned treatments, the web is pulled by the drive rolls 54 into engagement with the winding spool 55 upon which it is stored.

Depending upon the use to which the intermediate folded strip conductor is to be put, the necessary amount

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thereof is later unwound from spool 55 and rewound on conventional apparatus to final form. For example, in FIG. 4 a simple form of electrical coil 60 is shown having terminals 61 and 62. Since the interior surface 63 of the innermost turn of this coil is uninsulated, it will be understood that, if desired, a suitable separate insulating layer of material is interposed between that surface and the surface of the electrical device upon which the coil will be used. Many times it is desirable to leave this inner strip uncovered so that it may come into direct electrical contact with an electrical conducting member onto which it is mounted.

With the foregoing in mind, reference now is made to FIG. 5 showing in diagrammatic form two adjacent turns of coil 60 having an anodic insulating coating depicted in greatly exaggerated dimensions. Due to the smooth curved folded edges 18 and 19 which are devoid of the physical irregularities of the original edges 16 and 17, the passage of the strip through the bath has resulted in a substantially uniform thickness of anodic coating over those folded edges. This thickness is substantially the same as the thickness of the coating over the non-folded portion 21 of the same conductor. The uncoated portions 22 and 23 lie against the coated portion 21 of the adjacent turn and the peripheral insulation thus afforded each turn of the coil is substantially uniform. Thus, the use of doubled insulation between adjacent surfaces of turns of the same coil is avoided with consequent savings in cost and in overall size of coil.

In FIG. 6 a modification, wherein two turns of a coil, whose anodic insulation is applied prior to the folding operation, is shown. In preparing this form of strip conductor, the folding rolls 31 of FIG. 7 are omitted and similar folding rolls 31¹ are mounted between tank 35 and tank 51. In this case, the stock sheet 10¹ (FIG. 10) with its irregular edges 16¹ and 17¹ is moved through the bath using a wider central section 41 of the electrolytic roller. Upon passing through the folding rolls 31¹, the sheet 10¹ is folded, thus causing a partial fracturing of the inorganic insulation at edges 18¹ and 19¹, but not sufficiently as to destroy the insulating value of that coating for certain purposes. Subsequent treating of the thus folded strip upon leaving rolls 31¹ and as described above, further adds to the insulative values at edges 18¹ and 19¹.

As will be seen in FIG. 6, the entire second surface of portions 21¹, 22¹, and 23¹ is covered with the insulating coating, thus providing increased and surplus insulative value between the adjacent turns of the coil.

As will be apparent to those skilled in the art, many features of our invention may be employed independently of other features herein described. For example, we contemplate and consider as part of our invention, the use of a folded strip conductor insulated by conventional methods, such as lacquering a folded strip or folding a lacquered strip and wherein the specific anodizing treatment is not employed. Moreover, we contemplate the use of a folded conductor in the process set forth in the aforementioned copending application wherein the folding steps take the place of the brushing steps defined therein.

In addition, we contemplate by means of our invention the use of aluminum foils of such thin dimensions and small cross sectional areas and widths as heretofore have been impractical to use with any known process even employing interleaving sheets of insulating materials, such as Mylar.

Therefore, while we have shown a particular embodiment of our invention, it will be understood, of course, that we do not wish to be limited thereto, since many modifications may be made; and we therefore contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of our invention.

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What we claim as new and desire to secure by Letters Patent of the United States is:

1. In a method of producing an insulated metal conductor by the operation of an electrolytic bath and an anodic element partially submerged in said bath and including electrically conductive means and isolating means, the steps comprising: introducing an elongated metal strip continuously into simultaneous contact with said bath and said anodic element, with said conductive means contacting one side of said strip over an area which is large in comparison with the cross-sectional area of said strip, said isolating means contacting the same side of the strip as said conductive means and preventing said bath from contacting either said conductive means or the portion of said strip in contact with said conductive means, and said bath contacting the other side of said strip; passing an electrical current from said both through the thickness of said strip to said conductive means, with substantially no electrical current flowing from said bath through said isolating means to said conductive means, thereby forming a thin coating of insulating material only on the portion of said strip which is not in contact with said conductive means or said isolating means; and withdrawing the insulated strip from said bath and from contact with said anodic element.

2. In a method for producing an insulated electrical conductor from an elongated strip of electrically conductive metal having substantially parallel flat surfaces joined by substantially parallel irregular edges, the steps comprising: folding said irregular edges of said strip inwardly toward each other, thereby forming inner and outer strip surfaces; and passing said strip continuously into simultaneous contact with an electrolytic bath and an anodic element, said anodic element contacting at least a portion of the outer surfaces of the folded edges and keeping said portion, said irregular edges, and said inner strip surface out of contact with said electrolytic bath, so that a thin coating of insulating material is anodically deposited only on the remaining portion of said outer strip surface.

3. In a method for producing an insulated electrical conductor from an elongated strip of electrically conductive metal having substantially parallel flat surfaces joined by substantially parallel irregular edges, the steps comprising: folding said irregular edges of said strip inwardly toward each other, thereby forming inner and outer strip surfaces; and passing said strip continuously into simultaneous contact with an electrolytic bath and isolating means contacting at least a portion of the outer surfaces of the folded edges and keeping said portion, said irregular edges, and said inner strip surface out of contact with said electrolytic bath, while simultaneously applying an anodizing current to a portion of said strip out of contact with said electrolytic bath, so that a thin coating of insulating material is anodically deposited only on the remaining portion of said outer strip surface.

4. In a method of producing a completely insulated electrical coil, the steps comprising: producing according to claim 1 an insulated electrical conductor in the form of a single strip; and thereafter winding said conductor upon itself so that the uncoated portion of each turn is covered by the coated portion on the adjacent side of the next turn.

5. The method according to claim 1 wherein said metal is aluminum and said insulating material is aluminum oxide.

6. The method according to claim 2 wherein said metal is aluminum and said insulating material is aluminum oxide.

7. Apparatus for forming an electrical conductor from an elongated strip of electrically conductive metal having substantially parallel flat surfaces joined by substantially parallel irregular edges, said apparatus comprising in combination: means for folding said irregular edges of said

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strip inwardly toward each other to thereby form a thickened narrowed conductor having inner and outer strip surfaces and rounded outer edges; and electrolytic means for applying a thin coating of insulating material on the non-folded outer strip surface and on said rounded edges, said electrolytic means including a container for an electrolytic bath and an anodizing roller to be partly disposed in said bath, the peripheral surface of said roller having means for conducting an anodizing current to at least a portion of the outer surfaces of said folded edges, and means for isolating from said electrolytic bath said portion, said irregular edges, and said inner strip surface.

8. The apparatus according to claim 7, wherein said isolating means includes non-conducting resilient shoulders disposed at both sides of said conducting means.

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